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INTERNAL DOCUMENT No. 232

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CHINESE UNIVERSITY DEVELOPMENT PROJECT

Report on visit made by M.L. Somers, Institute of Oceanographic Sciences, Wormley, Godalming, Surrey, UK in November 1984 to The Radio Engineering and Automation Institute, South China Institute of Technology, Guangzhou, China.

NATURAL ENVIRONMENT RESEARCH COUNCIL
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CHINESE UNIVERSITY DEVELOPMENT PROJECT

The Radio Engineering and Automation Institute,
South China Institute of Technology,
GUANGZHOU, China.

Report on the Visit made in November 1984

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c.c. International Advisory Panel
Director, I.O.S.

THE SOUTH CHINA INSTITUTE OF TECHNOLOGY

Report of a Visit to the Radio Engineering and Automation Institute, November 1984 by M.L. Somers, Institute of Oceanographic Sciences, U.K.

1. SUMMARY I arrived at S.C.I.T. on Monday 5th November 1984 for a 29 day visit as a specialist invited to China under the Chinese University Development Project. This is my report to the Chairman of my host department, Professor Xu Bing-Zheng of my work during the month with my Chinese colleagues in the Sonar Laboratory. The following paragraphs cover in some detail the many topics we have discussed during the month. I start with a narrative of the visit including background and preparations. Then there is, mainly for my benefit and that of third party readers, a sketch of the structure of S.C.I.T. and the place of the Sonar Laboratory, including personnel and their responsibilities. This is followed by a history of S.C.I.T. achievements in civil sonar, and the laboratory strategy over the next 1, 3 and 5-10 years.

After this my report deals with specific problems and topics in side-scan sonar of immediate importance and in some cases urgency to S.C.I.T.

This section of the report is followed by a frank appraisal of the facilities, services, equipment and organisation available to the laboratory personnel. These are discussed in the light of the declared objective of the Laboratory management that among other things S.C.I.T. should be a key civil sonar establishment in China, and inevitably many deficiencies are highlighted. Noting the limitations of my observations and my opportunities in a short visit to understand fully the running of the laboratory and its relationship to the University administration, I nevertheless have made a multitude of recommendations in the field of laboratory running from furnishing to central university services, an ambience which at my home Institute I take for granted. In addition to the provision of these services, facilities and pieces of equipment I pay due attention to the importance of training to make efficient use of what will, if fully implemented, be an expensive investment.

Recommendations for training include return visits by S.C.I.T. personnel to I.O.S. and other European laboratories engaged in civil sonar, and this topic leads into ideas for a more enduring link between I.O.S. and S.C.I.T. The fact that S.C.I.T. has plans to develop its interest in long range side-scan sonar makes a link with I.O.S. particularly suitable. One further problem faced by workers at S.C.I.T. is that of overcoming the recent

isolation of the Chinese scientific and technical community from the International one.

I have tried to end the report on a hopeful note by drawing attention to the intellect, energy and enthusiasm of the Laboratory staff from the leader down, and to emphasise the great potential of this human resource if supported by the organisation, facilities and services which are routinely found in European and U.S. Laboratories.

2. NARRATIVE The origins of my opportunity to work at the South China Institute of Technology lie in the common interest at S.C.I.T. and I.O.S. in side-scan sonar. Contact was made when my colleague, Dr Rusby, visited S.C.I.T. in 1982 and met Professor Xu. The opportunity was provided by the Chinese University Development Project. I was appointed by the International Advisory Panel in February 1984 and started correspondence with Professor Xu at S.C.I.T. I had originally planned my visit for October, but this was soon changed to November to suit both me and my hosts.

My preparations were hampered by the difficulty of establishing effective communication with my hosts, and the situation was made worse by my heavy programme of seagoing in the spring and summer of 1984. However, we established the general subject areas, and I prepared topics for lecturing three or four times each week. In the event I gave a total of 15 lectures, one of which was an unscripted contribution to the Departmental seminar forming part of the S.C.I.T. 32nd anniversary celebrations.

I left England on November 2nd and after a night in Hong Kong, arrived by rail at Guangzhou on Sunday November 4th, where I was met by a party led by Professor Xu himself. I was initially accommodated in the Guangdong Guest House in the city, and travelled daily to S.C.I.T. by car. After a day or two I found this arrangement unsatisfactory and unnecessarily expensive, and I am very grateful that thereafter I was accommodated in an Institute apartment on the campus, which was highly suitable.

On Monday November 5th I had a welcome to S.C.I.T. and a tour of the Radio Engineering and Automation Department and the Computer Department. In the evening I was guest at a banquet in Guangzhou. Thereafter my routine consisted of lectures on Monday, Tuesday, Thursday and Friday mornings and discussions with the Sonar Laboratory staff on Wednesdays and most other afternoons. With this routine the days sped by. I was joined by my wife after a fortnight and we both made many friends in China.

During the last few days I drafted this report and discussed it with my hosts.

Finally on December 4th we had to bid our friends farewell and leave Guangzhou, after an unforgettable visit.

3. THE SONAR LABORATORY IN THE S.C.I.T. STRUCTURE This section is included only for the benefit of third party readers, who may not be fully aware of the structure of the South China Institute of Technology. S.C.I.T. has 19 teaching departments and 3 Research Institutes with no undergraduate members, but some M.Sc. and Ph.D. students. The 3 Research Institutes are:-

(a) Radio Engineering and Automation
(b) Materials Science
(c) Chemical Machinery.

Within the Institute of Radio Engineering there are 4 groups:-

(a) Underwater Sound
(b) Data Communications
(c) Image Processing
(d) Automatic Control.

These 4 groups have at the time of writing two Ph.D. students (one in Underwater Sound) and 38 M.Sc. students. The research and development projects undertaken by the Institute are supported either by local or National government, or by a 'factory' requiring the service. The National government is increasingly passing the burden of education and university research onto Provincial governments.

4. SONAR LABORATORY PERSONNEL AND RESPONSIBILITIES Again this section is for my benefit and that of third party readers rather than for the S.C.I.T. management who will be well aware of this information. The people working in the Sonar Laboratory are:-

Lin Zhen-Biao	Head of Group. Special interests are Civil Sonar and Bio Acoustic systems.
Yin Jun-Xun	Assistant Head. Interests are slant range correction, LFM systems, sonar display including TV.
Chai Han-Tian	Signal design, reverberation studies.
Liang Yao-Rong	Ph.D. student, signal design, LFM systems.
Dian Yue-Wu	Tape recording systems, digital recording.
Zhang Yuan-Bing	Receiving and transmitting systems.
Luo Guan-Xiang	Transmitter and LFM systems.
Xie Wen-Yun	Transducers.

and three Technical Assistants.

In addition the group brings in expertise from other departments for special purposes, for example the towfish to house the sidescan transducers was designed by Yuan Yi-Zhi and Zhang Nian-Fang, hydrodynamics specialists from the Ship Building Department, while the ceramic for the SGP-1 transducers was made in the Materials Science Department. That for the SGP-2 transducers was bought outside the Institute and assembled by the then head of the Sonar Laboratory, Yie Shi-Rao, who has since become head of the Radio Factory at S.C.I.T. The Materials Science Department has an interest in underwater transducers and piezoelectric ceramics, so that it should be possible to establish a good capability in this area if there are no barriers to interdepartmental groupings. The expert on ceramics is Mr Lin Shen-He. It is interesting and perhaps a comment on the difficulties of communication that this gentleman and I should have learned of each other's existence in a fortuitous manner. Mr Lin who has studied in the U.S.A. and likes to practise his English fell into conversation on the campus with my wife, and was amazed to discover that a specialist in a subject so closely related to his was visiting the Institute without his having any idea of the fact. For my part I am a little surprised that after several discussions on transducers and their problems, I should remain unaware of the existence at S.C.I.T. of an expert on piezoelectric ceramics.

5. HISTORY OF SONAR LABORATORY ACHIEVEMENTS Once more this section is for the benefit of third party readers, but bearing in mind the difficulties through which the Chinese higher education system passed in the period covered by the S.C.I.T. interest in side-scan sonar the achievements are impressive.

In 1971 the Department of Harbours approached S.C.I.T. for help in surveying for wrecks and other underwater obstacles. In response Lin Zhen-Biao produced, presumably with the help of the nucleus of his present team, the sidescan sonar, SGP-1. The Department of Fisheries also expressed interest with the idea of locating and charting seabed obstacles which might be a hazard to nets. In view of the difficult times, the lack of ability to produce on a routine basis close tolerance electro-mechanical engineering and the generally poor quality of such items as recording paper SGP-1 was in my opinion an astonishing success. When they started to publish some results the 2nd Marine Institute at Hangzhou noticed them and showed interest and support.

1976 saw a double triumph for SGP-1. First they were able within two weeks to locate a bucket string, lost by a Guangzhou Hydrographic Department dredger, when the Department had been searching for months without success. Second in the same year SGP-1 was used to survey the route of the China-Japan telephone cable.

By 1978 the Group were well advanced with the design and production of an improved successor to SGP-1, SGP-2. Technical aspects of these equipments will be discussed in a later section. Although China was by now no longer a closed country, and the Cultural Revolution was over, there were still increasing economic difficulties leading in 1978, in common with most other Chinese Universities, to a large scale re-scheduling of activities. The result was virtual suspension of work on sidescan sonar, and it is only in the last year or so that the Group has found support to take up the quest again. A considerable amount of work has been done on various parts of the system but some of the key improvements have thrown up technical problems which are dealt with in detail in a later section, and have formed the focal points of many of my conversations during my visit.

6. STRATEGIES OF THE SONAR LABORATORY OVER THE NEXT 1, 3 AND 5-10 YEARS

Having suffered a series of setbacks with SGP-2, both technical and economic, the Group is now grappling with the problems of re-starting its efforts in sidescan sonar, with several key technical problems unresolved and major operational difficulties in deploying the prototype SGP-2 for trials.

In spite of this the Group, and S.C.I.T. as far as I can gather, has an overall goal of putting the Group into the position of being a key laboratory in civil sonar and in particular sidescan sonar, with expertise and results which will meet China's needs in this field and stand comparison with similar equipment and results from Western sources.

In setting out this goal the Group leader has taken a pragmatic approach starting with a survey of sidescan sonar equipment available from Western sources, notably Klein Associates and E.G. & G. He has reached the practical and sensible conclusion that the Group should not dissipate their efforts by trying to cover the field of applications of these Western sonars, namely the 50 kHz to 100 kHz frequency band with single sided swath widths of 400 m to 1 km. It would take years to approach their level of experience in these areas of application and it would be difficult if not impossible for S.C.I.T. to devote comparable resources to development. In the light of my experience of sidescan sonar and what I have seen at S.C.I.T. I must agree that this is a very practical and sensible conclusion. This leaves two areas of application in which there is a good possibility of S.C.I.T., and China, holding its own. First there is the area in which S.C.I.T. experience lies, namely very short range high resolution sonar for site specific applications in general marine operations, harbour works, river and reservoir surveys, etc. The other area of application lies in long range sidescan sonar in deep water, with specific applications in the South China Sea on the continental margin and lower slope. Members of the Group are well aware of the interest of the British Institute of Oceanographic Sciences in this field of operation though due to the difficulties of contact with the International scientific community mentioned earlier and discussed below, the information available to them is both sketchy and out of date. Of course this interest in long range applications and awareness of I.O.S. involvement was the prime reason for my presence in China.

In view of the foregoing analysis and background I discussed at some length with members of the Group their plans and strategy for the future over various time scales, in particular one year, three years and five to ten years. These times were chosen by me and may not coincide with the time scales of the Group's plans.

The Group has essentially a complete sonar system in SGP-2, but as noted earlier with several major problems. The operational difficulties stem from the inclusion in SGP-2 of a 1.5 km range option requiring lower frequency (25 kHz-30 kHz) transducers nearly 2 metres in length. This choice meant that a larger towfish had to be produced, and because the new towfish was too big to manhandle, a winch is necessary. This in turn limits the number of suitable vessels for trials. The operational difficulties originate from the fact that the building of the new cable ship which was to have been the trials platform has been stopped. Also the winch has not been started or even ordered. In the face of this problem it has been decided that the small towfish with only high frequency transducers should be returned to service. This will enable the long overdue trials of SGP-2, at least in its high frequency mode, to take place. As an objective for 1985 I believe this is attainable and should be pursued. Even so there are significant developments with SGP-2 to be made before it can be operational. The most important of these is to complete a suitable display system. The plan is to use a dual system consisting of a TV monitor display with a fast refresh memory for short term display and a dry paper recorder for long term display. The latter recorder will have a digital buffer to enable a single stylus recorder to be used, so as to avoid the registration problems of a three stylus recorder. There will no doubt be further problems but I consider this approach to be practical and to offer better chances of success than trying to perfect the expansion of the 384 stylus recorder designed originally for installation in SGP-2.

One further plan in 1985 is to use a long coded acoustic pulse with correlation processing to improve signal to noise ratio. On arrival at S.C.I.T. I found this project fairly far along the road, but suffering from very severe technical problems. Much of my discussion time has been spent on this problem and we have worked out several alternative approaches. I would emphasise that in my opinion the Group are aiming at an unnecessarily high bandwidth-time (BT) product, in view of the short term exclusion of the low frequency option from SGP-2. The original specification was for as much of the system as possible to apply equally to both frequencies, and the designers have devoted considerable effort to achieving this. As a long term goal I would endorse this approach, but in my experience large BT products are not as necessary at frequencies above 70 kHz which is the approximate point at which thermal noise takes over from ambient noise as the performance limit. In the region of 200 kHz my recommendations would be to use a modest BT product of about 20 rather than 100, and to make absolutely sure that the pre-amplifiers have the minimum possible noise figure. The difference between 2 dB and 10 dB is greater than the difference in BT between 20 and 100. However, the important point is that after our discussions my colleagues and I are agreed on the most practical ways to realise correlation for various values of BT product.

The medium term objective which is to realise the full potential of SGP-2, with two frequency operation using the new towfish and a winch, depends upon the generation of cash in the short term. In fact the shorter term objectives with SGP-2 require financing by operations with SGP-1, so the whole programme depends upon generating a demand for services, which will generate cash to carry out the devebpment. The best chance of success under these conditions would I think be realised by setting up a small well trained section devoted to field work - ship-fitting, deployment and operation. Of course it goes without saying that the equipment should be constructed to good professional standards and adequately backed with spares, and the problems of packing and transport solved in a systematic way. This aspect of the Group's activities will need careful attention and an injection of resources. These resources will involve investment in technical methods and services before the department can expect a substantial cash flow from deployments of SGP-1. I did not discuss in detail the source of these funds but I assume that both the Provincial Government and the World Bank would have a part to play.

Assuming that the short and medium term strategies are successful, and that the Group enjoys a steady increase in demand for its services starting with SGP-1 and proceeding through the completion of SGP-2 with development of improved recording, signal processing and image display facilities, the leader can foresee in five or six years' time the need to consider extending into the second area of applications, namely low frequency deep water side-scan sonar. This area requires a very much larger investment both in engineering construction, because of the inevitably increased size of the tow-fish, and in the technical infrastructure at the Institute to support the very diverse engineering disciplines involved. Because of the gap between the technical support available now and that required to support a full spectrum of sonar activities I think it is important to start working towards this technological base now, while commitments are light and the financial stakes are relatively low. The long range sonar project will be in technical terms a fairly close equivalent to the I.O.S. GLORIA II, which had the advantages of I.O.S. experience with GLORIA I and of funding by UK Science spending, rather than being an investment decision based on estimates of the revenue to be gained from operational contracts. Even with these advantages the project would have been impossible without the many support services provided by I.O.S. for its scientific programme. These services include such things as a professional drawing office, an extensive workshop with modern machinery, the purchasing and contract management services available at I.O.S., financial and budgeting analysis, electronic construction facilities, the wide range of catalogue components available in the UK and many other aspects of the development environment, not least of which is ready access to a full-time ocean going research ship.

Having dwelt at some length on the Group's strategy over the next few years - possibly up to 10, the next section digresses a little to summarise our discussions on the immediate short term technical problems and decisions facing the Group, before I return in later sections to the facilities, skills and resources needed to support the medium to long term plans.

7. TECHNICAL TOPICS OF IMMEDIATE INTEREST My discussions with my Chinese colleagues have been concentrated fairly heavily in three specific areas which I assume to represent accurately the most pressing problems facing them. These areas are (a) realisation in accurate reliable hardware of signal correlation for BT products in the medium to large range (b) signal recording and display and (c) the reliable engineering of transducers. This seems to be the order of importance placed by the Group on the problems, though if direction of the Group were in my hands I would in view of the context of Section 6 above, place (a) last.

In all these three areas there is no lack of understanding or ideas from the laboratory staff. On the contrary they show great ingenuity, and analytical ability of a very high order. The problems are partly financial and partly the almost total absence of a 'middle layer' of what in the UK we call the support services. Of course the rate at which this middle layer can be replaced depends on both finance and the time taken to train personnel in the relevant skills. This problem will be discussed in some detail in a later section. For the rest of this section I will take the topics in the order given above.

(a) Signal Correlators In our discussions, my colleagues retraced the reasoning they had employed in arriving at their chosen solution to the problem of constructing a signal correlator. Starting from a requirement for a BT product of 100, and the intention to make the processor dual purpose for the two frequencies, they had considered in turn (i) Linear Passive networks (strictly speaking a passive realisation of an all-pass network with a linear group delay - an active or semi-active network is also available but had not been considered), (ii) Surface Acoustic Wave (SAW) devices, (iii) a Digital correlator using a dedicated multiplier integrated circuit and (iv) Charge coupled devices (CCD).

For a BT product of 100 the linear dispersive delay line approach is cumbersome and requires careful adjustment and good quality components if distortion and noise is to be kept below acceptable limits. For BT products below 30, and especially for linear frequency modulated (LFM) waveforms it would be my almost automatic choice, and for the short term single high frequency sonar this approach should in my opinion remain a candidate. It will take the least time of all four approaches to complete, and offers enough processing gain for a high resolution sonar operating near 200 kHz. I have handed over sufficient design information to make the design, production and alignment straightforward. The main problem with this approach is that the signal weighting to reduce delay sidelobes has to be performed in the frequency domain. However this process is easier with wide bandwidths than narrow, and the 4 kHz proposed for SGP-2 is a lot wider than the 0.9 kHz of the I.O.S. high resolution profiler for which we have developed a successful sidelobe suppression filter.

SAW devices offer very high processing gains and fairly wide dynamic ranges, but they operate on very high carrier frequencies with correspondingly short signal delays. This would make it necessary to use extremely high time compression factors with great complication in the electronic circuitry and a high degree of over sampling. Although I have no personal experience of SAW devices I would endorse the decision not to proceed with them for this application.

A fully digital approach may yet offer the only really satisfactory solution, but at present is baulked by the problems of finding a reliable and economic supply of the high speed multiplier chips needed. This is the approach I adopted for the GLORIA II correlator and it has proved to be very satisfactory, so there is no doubt it would solve the problem. The trouble is that the chips are not yet obtainable in China and import is a lengthy and expensive process. In view of the need noted above to provide adequate spares, it would appear that this solution is at present out of reach of the laboratory. There is however a possible modification to a fully digital correlator which would be realisable with components fairly readily available in China. The full digital approach requires a multi-bit reference, but since the amplitude of the stored reference is constant it is possible to use a one-bit reference in which case multiplication/accumulation reduces to either addition or subtraction, and TTL addition/subtraction circuits are available in China. There are quantisation problems which can be reduced by working at higher speed. At first sight the idea is attractive, and one advantage is that its performance can be modelled exactly on a computer before a single component is purchased. The laboratory has recently acquired an IBM PC and this would be a very suitable machine for running the numerical model. The GLORIA II correlator was modelled on a mini-computer before construction started and the exercise was well worthwhile. I believe that my colleagues agree on the potential attraction of this approach and I would endorse their intention to proceed at least with the numerical analysis and preliminary design.

CCDs are in my opinion an example of a bright idea which in the end poses more problems that it solves. Certainly in the S.C.I.T. sonar laboratory the CCD realisation of a BT = 100 correlator has run into serious problems in terms of signal variability and dynamic range. We have had similar experiences at I.O.S. in our one attempt to use CCD chips, and while I have not got the details to hand in China my clear recollection is that the system required tight AGC to function, which rendered it useless for sidescan sonar, but useful as a depth sounder. I cannot remember whether we had problems with signal stability. One further trouble is that the staff would encounter great technical difficulties in setting up a test bed which would isolate the source of the problem unambiguously. Until it can be pin-pointed with certainty it is impossible to challenge the claim from the makers of the CCD chips that the problem lies in the support circuitry.

(b) Signal Recording and Display The prototype display for SGP-2 used a composite write head consisting of a row of 384 styli set in epoxy. The styli were energised in turn by a hierarchy of switching transistors. The wet recording paper passed under this writing head over a metal roller. Apart from the general problems of wet paper facsimile records, namely distortion and shrinking of the paper, discolouration and fading with age and migration of high intensity marks, this recorder suffered from failure to meet the nearly impossible requirements for uniformity not only of the styli but of the contact force between paper and stylus. Also because of the voltage limitations of the switching transistors the marking power is limited in high sweep speed applications. These problems were just about bearable for the short section of 384 styli, but the prospect of obtaining satisfactory performance from a row two and a half times as long is very remote, and we are agreed that this is unlikely to be a profitable course to pursue.

We have had several discussion sessions on possible alternative courses of action. One possibility is to use conventional dry paper which will at least cure the problems arising from the use of wet paper. Of course it will not be possible to use the multi-stylus tip as marking takes place. We have considered the possibility of various three stylus arrangements, but as a result of experience with SGP-1 the Group members have a firm intention not to use a three stylus belt. In fact they have taken a very effective approach to making a three stylus recorder work and they have some first class records, but they assure me that it is a constant headache to adjust and I can well believe it.

We have discussed a one stylus belt which would have to be idle for over 60% of its time and would thus have to travel three times as fast to maintain an average real time record. The data can easily be held in a digital buffer for transfer to the paper during the correct phase. However for a full range of 160 m the stylus would have to traverse the paper in about 65 mS, and at this speed the dynamics of the stylus could easily cause trouble. The problem would be to raise the natural frequency of the stylus without losing compliance or raising the stylus pressure too high. We have however agreed that if these possible problems can be avoided this is a possibility, and I have agreed to send details of a similar digital buffer in use at I.O.S., not that the laboratory staff are unable to design one without any help from me.

To provide extra resolution over a 'zoom' range would at this pulse repetition frequency rule out any form of mechanical scan, so we have discussed the possibility of using a fibre-optic faced CRT with direct contact exposure of dry silver paper - a system which has been developed at Bath University in England. I have promised to gather as much information on this system as I can to send to China.

We have also had discussions on the design and use of a TV monitor display with a fast refresh memory. I have seen this in operation with a British sidescan sonar and it is very effective, but it is a transient record, once a line of data reaches the top of the display it must be discarded to make way for another at the bottom. At 160 metres full scale this means that the data is only available for inspection for two or three minutes. I have made it quite clear that I cannot see this system as a complete solution, because I attach overriding importance to obtaining a permanent record.

We have also had general discussions on magnetic recording methods. Due to the high information bandwidth and consequent data rate, magnetic recording presents certain problems. Analog FM recording is technically possible and offers the advantage of later replay at lower rates at least for selected images. A recording at 15 inches/sec on the IRIG wide band format would accommodate the bandwidth but a 2400 foot tape would only last 32 minutes which would become expensive on an extended survey. Digital recording would be cheaper once the initial high investment had been made, but this investment in both resources and effort would be considerable. I am quite satisfied that ultimately the best medium for presentation of sidescan sonar records is photographic film and the fewer steps the data takes in getting to the final film the better. This means that the optimum recording system is a digital magnetic record on computer readable tape with depth and navigation data keyed to the raw sonar data. This allows the use of a full range of image processing procedures so that files of processed sidescan data can be built up on a computer. After that the only process necessary is to produce a top quality image, and I believe the best way of doing this is to use a recorder writing direct to photographic film. At I.O.S. such a system using a laser and acousto-optical modulator is under development, with the added requirement of enough stability and ruggedness for use at sea.

It has not been possible to reach any definite conclusions on the best ways available to the sonar laboratory of recording and displaying data, but many issues have been clarified and we are agreed on a number of lines of action for the group.

(c) Transducer Construction and Testing If I have understood my hosts correctly the transducers for SGP-1 have a flaw in design or construction which results in leakage of water into the structure and consequent loss of insulation resistance. The SGP-2 transducer set has not yet seen service, but after a short inspection of it I would not seriously expect it to fare any better. Again there is no lack of understanding of the fundamentals of design and operation of underwater transducers, the weaknesses are all in the area of practical design and engineering shortcomings due to lack of experience and basic engineering services. Under present conditions it is impossible for the engineers responsible for constructing and testing the transducers to achieve the necessary degrees of accuracy, cleanliness and general high grade engineering to produce uniform high quality construction. Also because of the overall lack of control it is proving extremely difficult to build up the long practical experience which weeds out bad methods and techniques. This sort of experience is basic to successful underwater acoustics work and with the agreement of my Chinese colleagues I am making several specific recommendations in the area of design construction and testing of transducers. I am aware that there is in the S.C.I.T. considerable expertise in at least the theoretical aspects of piezoelectric ceramics, underwater plugs and sockets, the acoustics of transducer design and all the skills necessary to produce high quality transducers. What is lacking is, as ever, experience, top quality engineering support and if my analysis is accurate, the management structure to bring these skills together and build up a body of experience and capitalise on it. I can and do in a later section make some recommendations on the physical facilities needed for this sort of work, but it needs more than this in the way of organisation to make a success of it.

8. LABORATORY FACILITIES, TECHNICAL SERVICES, EQUIPMENT, ORGANISATION, ETC.

We come now to the description of the Radio Engineering and Automation Institute, and in particular the Sonar Laboratory built up partly from my own observations and also from the answers to questions I have put. Of course with the language barrier and my limited observation time these channels of information are not complete or necessarily quite accurate. Unfortunately I have to say that my overall impression is of primitive surroundings, poor facilities, lack of equipment and a generally uphill struggle to put ideas into effect.

The structure of the building seems sound but things like the decoration, the window frames, curtains, furniture are of cheap quality and often in poor condition. A great deal of dust accumulates in the corridors and laboratories, and the atmosphere is not ideal for a laboratory dealing with advanced electronic techniques. The humidity is high for most of the year and this combined with the Institute's proximity to an industrial city causes problems with air pollution, which affects particularly printed circuits, but also components, soldered joints and the silvering on piezoelectric ceramics. I emphasise that these conditions are not the fault of the staff and there is probably little to be done at this stage. However I noted that the Computer Centre is quite different. The Honeywell engineers have taken drastic and no doubt expensive steps to change the environment. Nevertheless these problems have to be noted because it will be necessary to take conscious steps to protect equipment from the ravages of the atmosphere and the dust.

Secondly I noticed a lack of modern techniques. In view of the nature of the instrumentation which the staff is attempting to construct, the basic electronic workshop facilities are almost entirely absent. The Sonar Laboratory has an electric drill but as far as I can tell no other workshop facilities at all. The list of basic facilities which are either inadequate or missing makes depressing reading, precision soldering with flux-cored solder, circuit drafting equipment, a light box for printed wiring layout, a professionally engineered prototype printed circuit unit, wire wrap tooling and circuit cards, convenient adaptable chassis systems for housing circuit cards. In addition I would regard as ill-equipped any electronic development laboratory which did not have a workshop with at least a bandsaw, a lathe, a drill press, vices, a brazing and soldering hearth, a printed circuit drill, a bending machine and variety of hand tools and measuring instruments. As far as I can see it takes the laboratory staff a lot of effort to gain access to any of these facilities.

Thirdly I noticed a lack of advanced development equipment for digital circuits and particularly micro-processor development. I was astonished and I must say filled with admiration when I learned that the largest micro-processor project yet undertaken in the laboratory had involved a 1K Byte Z80 program being assembled by hand and keyed into the micro in machine code - also by hand. There is also no logic analyser which I consider to be essential for digital work such as correlator construction and also for micro-processor interfacing. I later learned that there is a logic analyser in another department, which is a partial solution, but not really satisfactory for a laboratory of this size, since there is inevitably difficulty in arranging the timing and period of loans.

Another aspect of the laboratory organisation which causes me concern, though it may, due to language difficulties, be wholly or partially misplaced, is the apparent lack of interchange between groups, in the form of day to day working contact, exchange of services, lending of people and equipment, etc. Of course I have had no opportunity of learning about the department management and planning and for all I know there may be an effective Liaison Committee on which all the Research Institute's groups are represented and can call for special assistance when needed. I certainly hope so.

I have in this section made a rather long list of missing and inadequate facilities. Later I try to say how some of these can be put right, but here I would like to emphasise that in parallel with the physical provision of the facilities must go a programme of training in their proper use. However, I would also emphasise that the laboratory is blessed with an intelligent, talented and motivated staff, so that the long term prospects are very good.

9. THE SONAR LABORATORY IN RELATION TO THE UNIVERSITY

One of the things which puzzled me most during the early part of my visit, was the apparent isolation of the various groups from one another and from the main University services. As an example of this I was, on my first day, shown the Computer Centre, and I was immediately and forcibly struck by how lightly loaded it was. There were no operators on shift in the machine room, no disk packs or tapes were being mounted or dismounted and the system printers were almost idle. Even allowing for the system being new the loading was light as I would have expected the computer staff to be generating a lot of their own work. It also puzzled me that neither of my two guides had themselves visited the centre before. Again some time later I spoke to Professor Ou Yang in the Image Processing Laboratory and during his explanation of the work of the laboratory he mentioned the use of a microcomputer for image analysis, complaining that the computing load was excessive for his micro, which was clearly true as it requires nearly an hour to do a 256 × 256 point FFT. The point that struck me as odd was that his plans to alleviate his problems involved the purchase and/or construction of a hardware multiplier, and had no reference to the Honeywell, which could perform the above mentioned FFT in seconds at the most. In his place I would be planning in terms of a remote terminal and a time-sharing and batch account on the Honeywell. Then it would only be a question of interfacing to the display system. The answer to this puzzle came much later and is financial. The use of the Honeywell is charged for on demand, and the economics are such that a potential user finds it economically advisable, if not necessary, to spend endless time looking for cheaper solutions or just plodding on in the old way.

I believe that the financing of the computer operations should be arranged to encourage maximum use of the service. In my organisation in the UK the Natural Environment Research Council also runs a Honeywell (Series 66 which is a lot older than the 8/49), and all the component bodies such as I.O.S. have their effective budgets reduced by a certain amount to run the computing services, though the deduction is only a paper transaction. The services are then provided free on demand, though there is a form of post-accounting which adjusts the nominal contributions to reflect actual use. The point is that the services are paid for and available at zero marginal cost consequently there is a strong incentive to use them. Unless I am quite wrong about the purpose of the Honeywell, it seems to me that the need at S.C.I.T. is to bring computing to the teachers and researchers, and this fixed overhead form of pricing will certainly do that. Again I have since found out that a network of cables is being laid round the campus for connection to the Honeywell, so it may well be that when the connections are complete the accounting system will be set up to encourage widespread use of the facilities.

Another organisational problem that I have noticed concerns the placing of contracts between groups. My colleagues have placed a development contract with the Materials Science Institute to develop a waterproof plug and socket. This required payment in advance, but there seems to be no way for the customer to monitor progress and stage payments only by progress. This is probably a University Management problem, but as it affects my colleagues in their daily work I consider it worth mentioning here, especially as the example I have given is by no means unique.

Finally I must mention the purchasing procedures. As far as I could gather the central purchasing services at S.C.I.T. are rudimentary, and a lot of purchasing is on a cash basis. This deprives the Institute of many benefits not least of which is the ability to leave all the time consuming administrative chores to a special office devoted to and well equipped for the purpose. In addition a good purchase office provides an accurate and uniform method of record keeping; it can benefit from its wide experience of marketing conditions; it can provide reliable and rapid cash flow figures plus many other benefits. Certainly my Chinese colleagues gave me no indication that they have confidence in the system at S.C.I.T.

I mention these aspects of the University in its relationship with the Research Institute because the sonar laboratory cannot exist on its own, and the presence or absence of strong central management support can make or break a department.

10. <u>SERVICES AND FACILITIES REQUIRED BY THE SONAR LABORATORY</u>

In this section I try to list the major services and facilities which in my opinion are necessary to the efficient working of a laboratory engaged in the design of civil sonar. I realise that in aggregate putting these recommendations into effect will be a major investment and that they cannot all be done at once. Also the senior laboratory staff will need to have a clear idea of the sort of establishment they are trying to set up, and the training needed to support it.

First of all I have to assume that there is only limited room for improvement in the decoration, furniture and fittings of the laboratory. The space is kept clean and tidy but there is so much dust in the corridor and outside the building that with the high humidity the atmosphere in the laboratory is corrosive and it is difficult to keep equipment in good condition and untarnished. The only practical steps which can be taken to improve the situation would involve trying to reduce the amount of dust entering the room by maintaining the corridors in better condition and trying to limit the opening of windows when conditions outside are very dusty or very damp. The ideal of isolation and air-conditioning would be too expensive, but even partial air-conditioning would allow much reduced ventilation with consequently less pollution.

Next I would recommend that staff have access to a well equipped workshop and training in the use of tools and machines. These facilities could easily be shared by all the groups in the Radio Engineering and Automation Institute. In addition to the basic machines and tools listed earlier for this workshop and included in a separate Appendix there should be a good supply of electricity, water, gas and light, and adequate workbenches and hand-tools. The administration and maintenance of this workshop would have to be the responsibility of one skilled man whose major duty it would be.

In terms of specifically electronic facilities there is great difficulty in producing prototype electronic circuits that stand a chance of successfully surviving a field trip. Essentially there are two approaches to the construction phase of this problem, and both are necessary. First, if only one or two cards of a particular type are needed, and the circuit is a fairly complicated digital one (e.g. 20 ICs) then a wire-wrap board is a good way of making the circuit. The advantages are that no time-consuming and expensive art-work has to be produced, modifications are easy, the joints if well made are highly reliable, logic interference and cross-talk is limited and access to signal points for circuit checking is easy. On the negative side the actual assembly is time-consuming, the joints if not tightly and well made are absolutely useless, and circuit tracing is difficult. Wire-wrap is an essential technique for prototype digital work and I think the laboratory must be equipped for this work. What is needed is good quality tooling with semi-automatic strip and wrap for the wire ends, a range of standard cards to a recognised format (e.g. Eurocard, half single or double), a standard range of indirect multiway connectors and a set of standard card cages to hold the circuits. I am proposing to send representative literature and if possible samples to illustrate a suitable range.

Where the production run is more than 4 or 5, or less for analogue circuits, the appropriate technology is the PC board, but it is important to finalise the design and check performance before committing the design to production. The facilities needed are a light box, a supply of translucent film and black tape for laying out the copper tracks, a UV exposing box, copper laminate pre-coated with resist and a triple bath etching, washing and tinning processor. Again I would recommend indirect connectors, standard board formats and standard card cages. For long production runs external fabrication is best if quality and delivery can be guaranteed.

I will take an inventory of the I.O.S. PC facility on return to the UK and submit it as an Appendix to this report.

Both of these prototyping methods require two further facilities, first circuit drafting and documentation and second top quality precision soldering. While it is not necessary to go to the expense of complete Drawing Office equipment, some equipment is necessary, for example a board with parallel action ruler and dividing head, precision drawing instruments (either ink or pencil, the former gives better quality but requires greater skill and is more difficult to correct), a supply of standard drafting sheets and most important a set of conventions and rules for such things as circuit symbols, plug and socket numbering, catalogue numbers for the sheets, modification records, dates and other information, which form part of the complete history and description of an instrument. This job of setting up drafting standards is very important and care needs to be taken to get a satisfactory system at the earliest possible date. Finally, in terms of the basic technical competence of a good electronics laboratory and prototype production facility, it is essential to have up to date precision soldering systems. This includes temperature controlled irons, various bit styles and the best multi-cored solder with non-corrosive fluxes, in a selection of gauges.

These four basic services I regard as the most urgent and necessary improvements to the laboratory - namely wire wrapping, PC boards, drafting and soldering, but because they are so important it is essential to choose carefully, because the staff will have to live with the results for a considerable time. For that reason I would like to see a responsible member of the Group visit laboratories in the West including I.O.S., on a study tour before these important purchases are made. In fact these particular services are so basic to all electronic development that the necessary information could easily be gathered in Japan or even Hong Kong given the proper introductions. Certainly I.O.S. is not an ideal model for electronic production, but in view of my remarks and recommendations on acoustic transducers and testing it should definitely be on the itinerary.

Next I deal with the equipment and services needed to implement microprocessor solutions, not only in underwater acoustics but in any sophisticated real time instrumentation. In the Sonar Laboratory the preferred 8-bit processor is the Z80, and this is undoubtedly suitable for many tasks. Fortunately the Research Institute is already fairly well set up for implementing Z80 solutions. The Image Processing Laboratory has a full development system with editor/assembler, dual floppy disks and loading hardware and software. This system can be brought into use fairly widely particularly if it proves possible to transfer the main computational load of Image Processing to the Honeywell. In addition the Sonar Laboratory has a single board computer which can act as a system test bed and EPROM programmer. Furthermore they have an IBM PC and I have found a cross assembler for the Z80 to run on the IBM PC, which uses the editors supplied with the PC. The object files are in Intel Hex format, so that all that is required is an interface and a small loader program for the Z80 SBC to make a nearly complete development system. I understand that an emulator and de-bugger will soon also be available so that programs can be checked out for software errors before running in the target system. So with a small investment I can see that the Sonar Laboratory will be well equipped for Z80 development in the fairly short term. In the longer term there is a case for considering a high level language development system in the Honeywell. In my organisation in the U.K. the NERC Computer Services have installed a 'C' Compiler and cross assemblers for a number of target machines on our Honeywell. In this system the software is run and checked error free on the mainframe in the 'C' language, and the only processor dependent part is the final translation to object code. Although this is perhaps not a realistic idea yet, something of the sort could prove very useful at S.C.I.T., and it could be well worthwhile to have some information. One vital item in any laboratory developing fairly large scale digital systems, including signal correlators, and microprocessor based instruments is a logic analyser. At least 8 channels of timing and 16 channels of state recording with a 1K storage space are needed. Disassembly is not essential, but high speed timing with 'glitch' capture is vital. On several occasions at I.O.S. I have saved days if not weeks by having a logic analyser available. I understand that there is one in the Radio Engineering and Automation Institute, but the problems of sharing are always there, and I believe the Sonar Laboratory could justify exclusive ownership of one within a fairly short time.

The end of this rather long section of recommended services concerns the specifically acoustic instrumentation, and the most important item is undoubtedly an acoustic test tank with admittance/impedance plotting and calibration facilities. I have attached as an Appendix a description of recommended acoustic tank construction and placement, and I have discussed at length with my Chinese colleagues the instrumentation needed. This is also included in the Appendix. It is my belief that if the S.C.I.T. is to establish its position as a key sidescan sonar laboratory it must build up its transducer expertise and general acoustic technical experience. To do this a basic acoustic test tank is a minimum necessity.

11. TRAINING NEEDS

We are agreed that if all the services and facilities so far discussed are installed it will be important that they are fully used and for this to happen training in technique and skills will be necessary.

As a preliminary it will be necessary for a senior member of the Group who will be responsible for the effective use of the equipment, to make a tour of some laboratories where these techniques are in use and if possible to visit manufacturers and make a collection of catalogues. I see this study tour lasting 3 to 6 months with some time at I.O.S. and visits to other acoustic laboratories and laboratories with a heavy load of construction of prototype electronic systems. Most of the information needed can be found in the U.S.A., Japan or Europe, but if the main base is the U.K. it will build on the working relationship I have formed with the Sonar Laboratory staff and help to form the links between I.O.S. and the S.C.I.T. which I suggest in a later section as a desirable outcome of my visit to China. Also the person concerned would gain first hand observation of the I.O.S. acoustic measurements and methods, and could decide how to adapt and improve them for use in China.

The more detailed training of the rest of the laboratory staff in skills and techniques would be more gradual with a mixture of instruction and practice. This is essentially a day to day management matter, and the Group leader will know his staff well enough to deploy this training effort to best effect.

I also include under this heading a brief mention of technology spread. If the Sonar Laboratory is fortunate enough to be supported in this way, I have no doubt that the intelligence, care and enthusiasm the staff show in their present far from ideal working conditions, will ensure that the Group will make a success of their projects in sonar. In this case they will be noticed and I believe they will have a duty to share their experience and facilities as far as possible with other groups. In other words this development would be a prototype for other research groups at the S.C.I.T. to emulate and improve.

12. TOPICS DISCUSSED DURING MY VISIT

Although the text of my report will already have revealed many of the topics discussed during the 18 sessions of laboratory meetings, the following is a list culled from the diary I have kept during my visit. In fact my laboratory sessions started on Wednesday, 7th November when I had moved out from Guangzhou to the campus, so that it was very much easier for me to attend the laboratory for afternoon talks.

November 7th:- 2 sessions on GLORIA II, the I.O.S. long-range sidescan sonar. The talks covered all aspects of the design and operation, particularly towfish construction, transducer performance, towfish stability measurements, acoustic beam stabilisation, data recording, image corrections, conduct of surveys, production of final images and many other details.

November 8th:- One afternoon session trying to prepare a typescript description of the GLORIA II system on the IBM PC. This was to enable my Chinese hosts to read the results of the previous day's discussion, my handwriting being understandably incomprehensible to them. In fact I only managed to produce a technical specification.

November 9th:- One afternoon discussion on the experiences of the S.C.I.T. sonar group, with great emphasis on their three main problems as detailed earlier. By this stage my notes contain 6 topics on which I can help my hosts with further description or technical literature.

November 12th:- One afternoon session with discussions on the S.C.I.T. approach to slant range correction. This was followed by more discussions on the technical aspects of graphic recorders, and the GLORIA logging and display procedures.

November 13th:- One afternoon session on recorders again. In this I got full details of Mr Yin's algorithm for slant range correction using the Z80 microprocessor. This was when I learned to my astonishment that he had actually assembled a 1K Byte program by hand (see my remarks above on development systems). We also discussed CRT presentation of records, and the Denbigh swath bathymetry system. I increased my list of technical literature to send on return to U.K.

November 14th:- 2 sessions both on the S.C.I.T. experience and plans with large BT product correlators. The second session consisted of bench work on the S.C.I.T. CCD correlator and its problems. This day also contained the discussion of the characteristics and use of AGC in sidescan sonar.

November 15th:- One afternoon session discussing the S.C.I.T. plans for a digital correlator with a BT product of 100. We discussed various ways of getting round the difficulties they have in obtaining high speed multiplier/accumulator chips. I suggested a modification of the digital correlator using a 1-bit reference which may be of use.

November 16th:- A short morning session after my lecture to the 32nd Anniversary symposium on GLORIA II. It was in the Image Processing Laboratory with Professor Ou Yang, and we discussed many topics of common interest.

November 21st:- 2 sessions. The morning was spent discussing the GLORIA II digital correlator in as much detail as I could produce from the material I had in China. I can send further details on return to UK. Also we discussed the GLORIA pulse power amplifiers. In the afternoon we were joined by Mr Zhang of the Ocean Engineering department for talks on towfish design and he showed me details of his paper analysing towfish stability.

November 23rd:- One afternoon session split between a further short talk with Mr Zhang, and the first major session on my preparation for this report.

November 26th:- One afternoon session discussing the strategy of the Sonar Laboratory over the next few years.

The remaining technical sessions were spent either preparing the draft report or clearing up details from previous sessions where the attempt to draft the report had indicated doubt or incomplete notes or information.

13. FUTURE CONTACT AND EXCHANGES BETWEEN I.O.S. AND S.C.I.T.

We are all fully in agreement that this first month's contact has been most fruitful, not only in the detailed technical recommendations given earlier, but in a wider cultural sense, and we would both be very disappointed if the contact should cease here. Indeed my Director has said he would be interested in seeing I.O.S. form scientific links with institutes of similar interests in China. It is partly for this reason that I have recommended that the proposed technical study tour should prominently include a visit to I.O.S.

Beyond this growth of contact will be limited by financial considerations but I would hope eventually to see reasonably extended exchanges of working visits and joint publications. In the meantime it costs very little to exchange collected reprints and annual reports.

There is not at this stage much point in setting up a formal structure linking the two Institutes and indeed the difficulties of defining such a structure make it inadvisable at present. I believe that a steady informal exchange of results, news and, as often as possible, personnel is the best way for the link to grow.

If cooperation between I.O.S. and S.C.I.T. can be developed, even to the point of joint publications, then for some time the main Chinese contribution will lie in the areas of theory and detailed numerical work where they are particularly strong.

14. CONTACT WITH THE INTERNATIONAL SCIENTIFIC COMMUNITY

My short stay has assured me that the academic staff of S.C.I.T. has much to offer in the theoretical and analytical field, and in due course will also have much to offer in the way of results in such subjects as sidescan sonar. I have also noticed that they have a problem getting papers accepted due partly to not knowing where to submit and partly to difficulties with style and precision in English (or French, German, etc.). I am helping my colleagues in a small way in individual cases but as a nationwide problem I think it deserves attention from the CUDP. My belief is that when the West becomes used to seeing high quality contributions to the scientific and technical literature, as it certainly could, then the exchange of information will accelerate and this will aid the growth of technology in China and hence the development of China itself.

15. SPECIAL INTEREST AT S.C.I.T. IN LONG RANGE SIDESCAN SONAR

Since I.O.S. is at present the only establishment in the world actively pursuing the development of long range sidescan sonar, and the Group at S.C.I.T. has the intention in due course to enter this field, continuing contact between the two Institutes is a sensible and natural action, and this interest can be used to foster wider contact.

16. CONCLUSION

My report ends with a summary of agreed conclusions to the month's work and a list of recommended actions, followed by a brief valediction.

I have agreed the following with my Chinese colleagues as practical goals:-

(a) To develop SGP-2, in the short term as a high resolution improved successor to SGP-1.

(b) To aim to upgrade SGP-2 to the originally intended specification within the next 2-3 years.

(c) To exchange information on the technical items covered in the discussion sessions with a view to developing cost-effective signal correlators, graphic displays and signal recorders.

(d) To set out to gain experience and skill in designing and testing underwater transducers.

(e) To confine sidescan development largely to the two regions of very high resolution short range work and long range deep water work.

(f) In the longer term to investigate and enter the field of long range sonar construction.

In addition I recommend the following improvement plan for the laboratory in the hope that it can be detailed, costed, planned and acted upon.

(g) To do what is possible about the general ambience of the laboratory:- the decoration, furnishings, light, plumbing, electricity supply, etc. to reduce the working difficulties.

(h) To send a senior Group leader on an extended (3 to 6 months) study tour, at least partly to I.O.S. and based on his report and my further recommendations below.

(i) Establish a workshop as detailed in Section 10 and to ensure that staff are trained in the use of necessary machines and tools.

(j) Improve the basic electronic construction facilities in terms of soldering, PC design, PC fabrication, wire-wrap technology, standard cards and connectors and other improvements as detailed in Section 10.

(k) To upgrade the digital circuitry capability and microprocessor development facilities as detailed in Section 10.

(l) To set up a transducer test facility as detailed in an Appendix, and to gain experience in design and construction.

(m) To carry out training programmes in all these techniques as necessary.

(n) To maintain contact with I.O.S., to exchange information results and technology.

This concludes the substance of my report, but I would like to repeat my thanks both to the South China Institute of Technology and my host department for the privilege of working with them for the month, and for the great goodwill and friendship with which I have been welcomed. I would also like to record my whole-hearted admiration for my lecture audience who persevered with good humour and friendliness in spite of my indifferent lecturing style and my frequent disregard of the language barrier.

January 1985. Michael L. Somers.

APPENDIX A   ACOUSTIC TEST TANK FACILITY

The body of the report in several places mentions the need for a transducer test tank. This appendix lists a few of the more important technical aspects of its design.

(a) Siting   The ideal is to have the tank and its associated engineering and instrumentation both near the laboratory and under cover. At IOS the tank is within the main engineering workshop and assembly area. If it has to be in the open there must be a laboratory building alongside, which is dry, lockable and has a supply of electricity. The laboratory space should be greater than 6-10 square metres with workbench and shelf space.

(b) Dimensions   Since the ideal test conditions are 'free field' it follows that any dimensional restriction involves a limitation which gets more severe the lower the frequency. Beam pattern and other measurements using a calibrated hydrophone will normally use pulse techniques, where the distance to the nearest boundary is what matters, when taken in conjunction with the frequency and bandwidth of the transducer. For measurements above 10 kHz experience has shown that it is possible to achieve good results with a tank over 4 m long by 3 m wide and 3 m deep. It is most economical for the two smaller dimensions to be equal and for one of them to be the depth.

(c) Construction   For good practical and acoustic reasons the best method of construction is for the top of the tank to be at ground level. The strength is best provided by making the outer casing of reinforced concrete in which case it could be necessary to provide some absorptive lining to reduce the reverberation time. The tank needs a cover to prevent contamination of the water (and accidents). At IOS this is provided by a set of steel beams and rectangular panels of heavy plywood. If the tank or a substantial part of it has to be above ground, wood is a suitable construction material for its strength and acoustic absorption. Redwood, cedar or cypress planks 6-10 cms thick and held together by steel tie-rods is a satisfactory form of construction. A tank above ground needs to be spanned by a bridge to gain access to the centre.

(d) Lining   The IOS tank has no lining at all except its special paint, and gives acceptable results above 10 kHz. However, an absorptive lining will enable better admittance plots to be obtained, and will allow higher pulsing rates for pulse measurements. A cheap and acceptable material is Insulkrete, a cement and sawdust mixture. This can be made in rectangular wedges up to 0.5 m long with a wedge angle of about 15°. Lining the bottom and sides with these wedges will substantially reduce the reverberation time, and reduce any tendency for standing wave patterns to form. There is seldom any need to line the surface with an absorber, and it has to be remembered that absorbent wedges reduce the effective tank dimensions.

(e) Treatment Because of the tendency of biological activity to generate bubbles of gas, and the uncertain and undesirable acoustic effects of these it is wise to treat the water with an algicide. It also helps if the cover is light tight.

(f) Equipment The essential fixed equipment consists of the admittance plotter (oscillator, counter, X-Y plotter and the vector admittance bridge of which details will be supplied to S.C.I.T.), a calibrated hydrophone, signal gating unit, oscilloscope, amplifiers and rigging arrangements which can be built up over a period on an ad hoc basis. In my experience it is sufficient to construct a turntable of simple form when required.

(g) Documentation Apart from the handbooks of proprietary equipment the documentation should include general instructions, standard plotting sheets and a day book recording all the experiments and summaries of the results.

APPENDIX B INVENTORY OF P.C. PROTOTYPE ROOM

The IOS room for the production of prototype P.C. boards is a separate room 4.6 m × 3 m with single access door. The door is lockable and there is a restricted distribution of keys.

The room has fluorescent lighting to provide general illumination and extra incandescent illumination at certain points. The electricity supply is available at multiple points round the walls. There is a supply of hot and cold fresh water to a general purpose sink, and a separate plumbing system for the spent chemicals, which are collected in plastic containers and disposed of by a waste contractor. There is a fume extraction fan with trunking to the outside and the room is provided with benches, drawers and cupboards. The equipment comprises:-

1. Foot operated guillotine with 1 metre blade.
2. Corner-rounding punch.
3. Precision drill with selection of tungsten carbide bits 0.5-4 mm. The drill has a lamp, stereo low power microscope, extractor fan and ear muffs. Operators are issued with dust masks and instructed to use them.
4. Weller de-soldering station.
5. Combined ultra-violet and yellow light timed exposure unit, 0.5 m square, with safety cover for U/V light.
6. AUTOPOS four bath printed circuit station consisting of developer, wash, etching and electroless tinning baths.
7. Ultrasonic cleaner - 2 litre capacity.
8. AUTOPOS gold plater.
9. Thermostatic drying cabinet, with fan ventilation.
10. Refrigerator.
11. Accessories such as measuring beakers, dishes, funnels, etc.
12. Stock of all materials including pre-coated copper clad laminate for positive system working.